Computational Materials Science 129 (2017) 123–128

Contents lists available at ScienceDirect

Computational Materials Science

journal homepage: www.elsevier.com/locate/commatsci

Simulation analysis of co-continuous ceramic composite dynamic mechanical performance and optimization design

Qingxiang Wang [a], Hongmei Zhang [b,*], Hongnian Cai [b], Qunbo Fan [b], Guoju Li [b], Xiaonan Mu [b]

[a] Institute of Electronics, Chinese Academy of Sciences, Beijing 100190, China
[b] National Key Laboratory of Science and Technology on Materials Under Shock and Impact, School of Materials Science and Engineering, Beijing Institute of Technology, Beijing 100081, China

ARTICLE INFO

Article history:
Received 10 October 2016
Accepted 6 December 2016

Keywords:
Co-continuous ceramic composites
Dynamic behavior
Numerical simulation
Optimization design

ABSTRACT

In this paper, a generation-based optimization method is proposed to reconstruct three-dimensional (3D) finite element (FE) model of co-continuous SiC_{3D}/Al composites. Investigation of dynamic numerical simulation is applied to the model. Then an optimization design of different infill materials, volume fractions and distribution characters is proposed. After research among the three infill materials of Al, PU and epoxy, the SiC_{3D}/Al composites have the best dynamic behavior. Then different SiC_{3D}/Al composite models are reconstructed by changing the volume fraction and core distribution probability in the reconstruction method. The results indicate that the peak stress raise significantly along with the increasing of SiC volume fraction. But in the unloading stage, the composites appear a sustaining compressive capacity when the SiC volume fraction is lower. Remaining mass rate and failure contour are studied to research the failure process. The stress is also influenced by the distribution characters significantly. At last, the composites are optimized.

© 2016 Elsevier B.V. All rights reserved.

1. Introduction

Co-continuous ceramic composites [1–3] consist of two interpenetrating networks. Other than the particle-reinforced composites or the fiber-reinforced composites, both of the two phases are interpenetrating and continuous. On the one hand, the volume fractions and two-phase distribution characters display varied morphologies, which can significantly affect the composite physical and mechanical properties, such as strength, toughness, and fracture resistance. On the other hand, the various materials of the two phases also influence the behavior of the entire composites under different loading conditions. Along with the research and development of various composites, co-continuous ceramic composites gradually show their unique properties and are thus applied in automotive, aerospace, packaging and thermal management of electronic devices [4–6].

In the traditional method, investigations of co-continuous ceramic composites need several experiments to analyze the effects of volume fractions, distribution characters, and material types on the infill and matrix phases. As a result, the finite element method (FEM) is proposed to examine the properties co-continuous ceramic composites. Many researchers performed several studies on co-continuous ceramic composites. Lan [7] considered the co-continuous composites as an entirety phase to accomplish the thermal and stress analyses of a SiC/6061Al composite during emergency breaking. Feng [8] proposed a unit cell model to determine the overall effective properties of composites reinforced with either dispersed inclusions or interpenetrating networks. Wegner [9] selected a hexagonal array of intersecting, uniformly sized spheres to present the interpenetrating phase composites to study the mechanical properties via FEM. Li [10] adopted a micro-CT technology to obtain a 3D model and examine the dynamic behavior of interpenetrating composites. The simulation studies on this the material mainly focus on 3D modeling and the simulation method.

In the present work, a generation-based optimization method is proposed to reconstruct the 3D finite element model of co-continuous ceramic composites. The microstructures of composites can be changed using the reconstruction method. Dynamic compression simulation is applied to the model to study the dynamic behavior. The same simulation is then applied to models of different volume fractions and distribution characters reconstructed by the generation-based optimization method to complete an optimization design, which can enhance the microstructure of the composites.

* Corresponding author.
E-mail address: zhanghm@bit.edu.cn (H. Zhang).

http://dx.doi.org/10.1016/j.commatsci.2016.12.009
0927-0256/© 2016 Elsevier B.V. All rights reserved.

2. Three-dimensional model reconstruction

The special continuous structure of the co-continuous ceramic composites in this work is derived from their forming process. This process is described as follows: First, the ceramic particles are accumulated in a stacking manner. The ceramic phase is then prepared by sintering to form a skeleton. The interpenetrating ceramic phase also formed the interpenetrating pores. Second, melt metal is infiltrated in the pores by vacuum pressure infiltration. As a result, both the skeleton and the infill phases are continuous in the composites. The scanning electron microscopy (SEM) image of co-continuous SiC_{3D}/Al composites is shown in Fig. 1, in which the brighter area is Al, and the darker area is SiC. The SEM image measures 1 mm × 1 mm. The Al and SiC phase volume fractions are 16.1% and 83.9%, respectively.

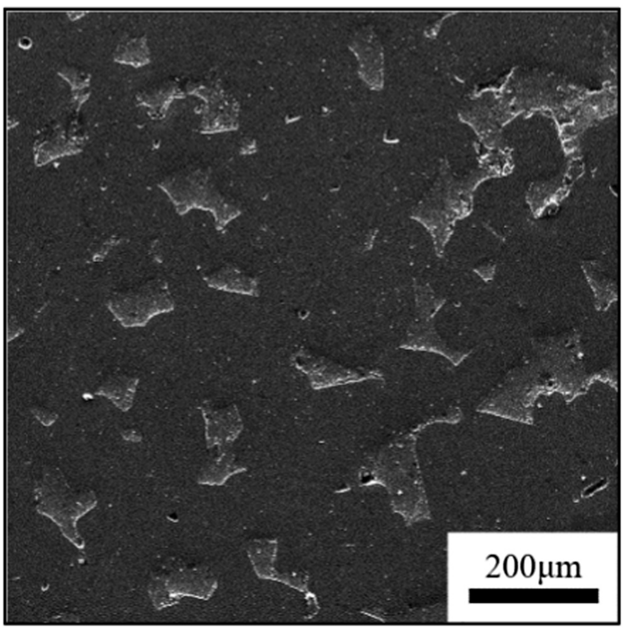

Fig. 1. Co-continuous ceramic composite SEM image.

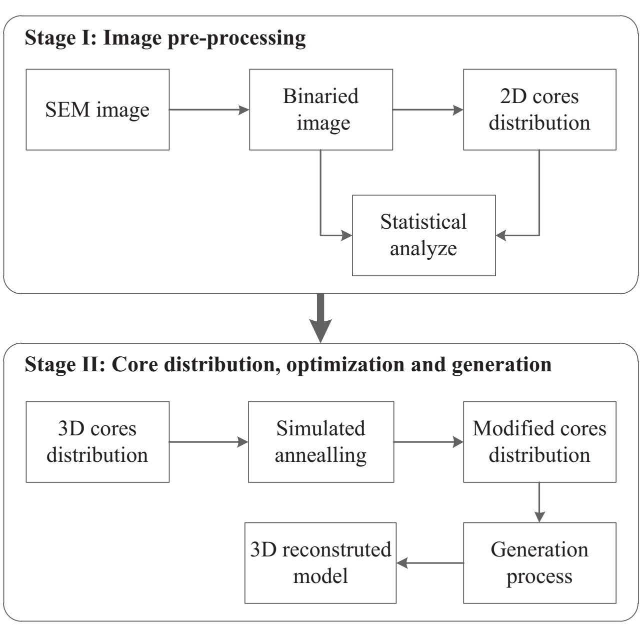

Fig. 2. Flowchart of generation-based optimization method.

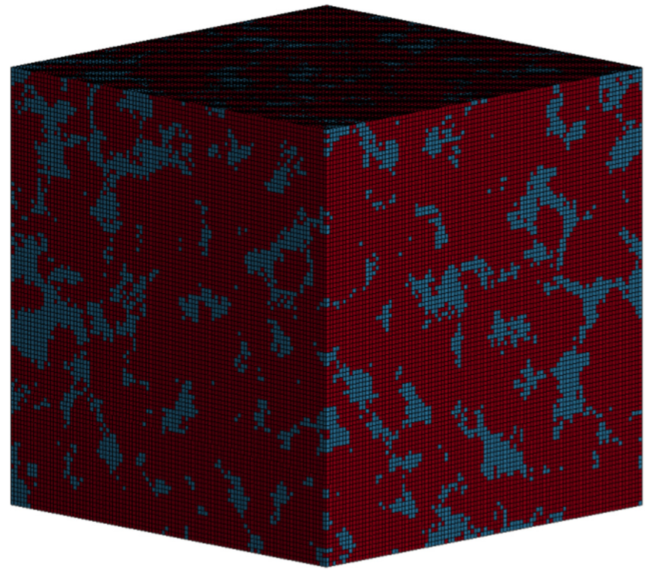

Fig. 3. Co-continuous ceramic composite 3D FE model.

The generation-based optimization method [11] is adopted to reconstruct the 3D finite element model of co-continuous ceramic composites. The flowchart of the generation-based optimization method is shown in Fig. 2, in which the SEM image displays the foundation of the reconstruction method. Through binarization, generation core distribution, and generation core optimization, a 3D finite element model is proposed.

The SEM image of co-continuous ceramic composites in Fig. 1 is adopted in the generation-based optimization method to reconstruct a 3D finite element model as shown in Fig. 3, in which the matrix is the ceramic phase, and the reinforcement is the metallic phase. The reconstructed finite element model measures 1 mm × 1 mm × 1 mm. The metallic and ceramic phase volume fractions are 13.1% and 86.9%, correspondingly.

3. Numerical simulation and optimization design

The dynamic behavior of co-continuous ceramic composites under an impact loading condition is studied in this work. The finite element model in Fig. 3 is imported to ANSYS/LS-DYNA to analyze the dynamic mechanical properties of the composites.

3.1. Material properties

The infill and matrix phases were Al and SiC, respectively, in the finite element model which can be described by the Johnson–Cook [12] and Johnson–Holmquist constitutive models [13].

The Johnson–Cook model is generally used to describe the metallic phase. The parameters of Al in the simplified Johnson–Cook model are listed in Table 1 [14].

The Johnson–Holmquist model is generally used to describe the ceramic or glass materials for their brittle behavior. The parameters of SiC in the Johnson–Holmquist model are listed in Table 2 [15].

Table 1
Johnson–Cook model parameters of Al.

ρ/kg·m^3	E/GPa	μ	A/MPa	B/MPa	n
2712.6	68.95	0.33	50	157.44	0.3002

Download English Version:

https://daneshyari.com/en/article/5453460

Download Persian Version:

https://daneshyari.com/article/5453460

Daneshyari.com